Clinical Application of Long-term Palindrome Catheter in Hemodialysis Patients

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Introduction. This study was conducted to compare catheter function, dialysis adequacy, and dialysis-related complications among patients receiving long-term dialysis via Palindrome catheter, Permcath catheter, and arteriovenous fistula (AVF) as vascular access.

Materials and Methods. Forty-three patients undergoing dialysis with Permcath catheter, 49 with Palindrome catheter, and 56 with AVF were recruited. Urea clearance (KT/V), urea reduction rate, and the highest blood flow at the arteriovenous junction during dialysis were determined during the dialysis sessions. Catheter-related infection, catheter-associated thrombosis, and annual patency rate were also evaluated.

Results. In patients using Permcath catheter for dialysis, the incidence of secondary renal injury (metabolic diseases, hypertension, and ischemic kidney diseases) was 73.1%, which was significantly higher than that in patients with AVF (51.5%; $P < .001$). In the Palindrome group, maximum blood flow, KT/V, urea reduction rate, and annual patency rate were significantly higher than those in the Permcath group, and the incidence of access-related infection was significantly higher than that in the AVF group. In the Palindrome group, the prevalence of thromboembolism was 30.6%, which was significantly lower than that in the Permcath group (46.5%), but higher than that in the AVF group (5.4%).

Conclusions. For dialysis patients, Palindrome catheter was superior to Permcath catheter and comparable with the AVF in terms of the maximum blood flow, dialysis adequacy, and annual patency rate. Dialysis with Palindrome catheter has a high infection rate and a high incidence of thromboembolism as in the dialysis with Permcath catheter.

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INTRODUCTION

With the increased prevalence of diabetes mellitus, vascular access has been a major problem in patients receiving long-term hemodialysis. Favorable vascular access is a prerequisite for successful and adequate dialysis. Currently, vascular access options for dialysis include arteriovenous fistula (AVF), long-term dialysis catheter, and Teflon-based synthetic vascular fistula.

Basic research focused on the stenosis of AVF and synthetic vascular fistula and most of applied research emphasized the clinical application of long-term dialysis catheter.[1,2] In recent years, increasing studies have been conducted to investigate the application of long-term catheters in dialysis patients.[3-5] This may be attributed to that most patients have advanced age and often present with poor condition for preparation of vascular

access. Although catheterization technique has been improved, long-term application of catheter for dialysis still has some complications such as catheter-related infection, thrombosis, high incidence of catheter dysfunction, low blood flow, and high rate of recycling. Particularly, catheter-related infection, thrombosis, and formation of perivacular fibrous sheath have been the major causes of catheter dysfunction. Increasing studies have conducted to investigate these complications related to indwelling catheter.[6-8]

Long-term tunneled central venous dialysis catheters containing polyester cover can be used as a vascular access for long-term dialysis and mainly used in patients in whom the preparation of AVF is infeasible (especially the elderly patients). In the United States, more than 50% of patients receiving long-term dialysis are dependent on venous catheter and synthetic vascular access.[9] The most effective way to reduce the catheter-related complications is to avoid the application of catheter.[10,11] In China, the number of patients receiving hemodialysis increases. For patients in whom preparation of AVF is infeasible, long-term application of dialysis catheter is inevitable. However, there are some challenges in the application and management of long-term dialysis catheter. There is a long way to go for physicians engaging in the blood purification therapy to solve these problems.

The central venous dialysis catheters containing polyester cover have been applied for long-term dialysis. On the basis of problems in application of previous catheters, a new generation of long-term dialysis catheter, called *Palindrome catheter*, has been developed. A symmetrical "Z" shape outlet is designed at the end of the catheter, which may reduce the risk for poor blood flow due to contacting of catheter with vascular wall and then increase the dialysis adequacy. In our Department of Nephrology, a large amount of patients received dialysis with this catheter in the past 4 years. In this report, we compared the findings in the application of Palindrome catheter with receiving dialysis with other catheters or AVF.

MATERIALS AND METHODS

Participants

Patients were recruited from November 2007 to May 2011. A total of 56 patients received dialysis with Permcath catheter (Tyco International, Boca Raton, Florida, USA), of whom 43 had complete clinical information (Permcath group); a total of 74 patients underwent dialysis with Palindrome catheter (Covidien, Mansfield, MA, USA) of whom 49 had complete clinical information (Palindrome group). In the same period, 134 patients received dialysis via the AVF of whom 56 had complete clinical information (AVF group).

Procedures for Catheterization

Procedures were performed by an interventional nephrologist. Palingdrome 14.5-F and Permcath 13.5-F catheters were used in the Palingdrome group and Permcath group, respectively. On the basis of surface landmarks and the bilateral internal jugular veins, the length of catheters was 36 cm, 40 cm, or 45 cm. Catheterization was done at local anesthesia. On the day of catheterization, ultrasonography of the bilateral internal jugular veins was performed and followed by catheterization with Seldinger technique and avulsion dilatation catheter. The subcutaneous tunnel was about 10 cm in length and the polyester cover was about 2 cm to 3 cm away from the outlet of the catheter. The outlet of the catheter was covered with sterile gauzes. After catheterization, hepatin or hepatin (50%) was administered.

Dialysis Care

Dialysis was done with polysulfone dialysis membrane (1.4 m^2 to1.6 m^2 in area) and bicarbonate dialysis solution in all patients. The flow rate of dialysis solution was 500 mL/min and dialysis was done for 4 hours per session and 2 to 3 times weekly. Before connecting the catheter, the outlet was sterilized and a residual hepatin solution was removed, followed by injection of fresh hepatin solution. Then, the catheter was connected to the machine for dialysis. After dialysis, the catheter was washed with 10 mL of 0.9% sodium chloride to remove the residual blood, followed by addition of hepatin. The catheter was clamped to avoid the contra-flow of blood and thrombosis. The cap of the catheter was replaced after each dialysis and experienced sterilization. The physicians closely observed the sterilization of the catheter outlet, and the local presentations (redness, swelling, tenderness, and secretions), and the gauges were refreshed timely.

Management of Complications

Urokinase, 25 000 U/mL, was injected monthly to avoid thrombosis. The procedures for treatment of poor blood flow or thrombosis were as follows: urokinase was injected to the catheter and stayed in the catheter for 30 minutes, followed by withdrawing urokinase solution. This was done thrice. When this management failed to improve the blood flow, 250 000 U was mixed in 50 mL of normal saline followed by injection with a micropump, which was done for 30 to 60 minutes (25 mL per side). Inflammation around the catheter was treated by changing dressings and focal or systemic application of antibiotics. When catheter-related chills and fever were suspected, blood culture was done, and corresponding antibiotics were administered to the catheter. Systemic administration of antibiotics was done if necessary.

Observations

The urea clearance rate (KT/V) and urea reduction ratio (URR) were determined. The maximum arteriovenous blood flow was measured at first dialysis. In addition, the infection, thrombosis, and catheter patency were observed. The URR and KT/V were calculated as follows:

$URR = 1 - R$

$KT/V = -\ln(R - 0.008 \times \text{time}) + (4 - 3.5 \times R) \times (\text{ultrafiltration rate}/\text{dry weight})$

where R is urea nitrogen after dialysis divided by urea nitrogen before dialysis.

Statistical Analysis

Statistical analysis was done with the SPSS software (Statistical Package for the Social Sciences, version 10.0, SPSS Inc, Chicago, Ill, USA). Quantitative data were expressed as mean ± standard deviation and comparisons were done with the *t* test. Qualitative data and rates were compared with the chi-square test. A value of $P < .05$ was considered significant.

RESULTS

Patients

After recruitment, 130 patients received dialysis with Permcath catheter or Palindrome catheter, which accounted for 49.2% of patients receiving dialysis in the same period. However, Permcath catheter or Palindrome catheter was used in only 46 patients at first dialysis accounting for 17.4%. Among the causes of kidney failure, secondary renal injury (such as metabolic diseases, hypertension, ischemic renal diseases, and others) was found in 95 (73.1%) patients in 130 patients receiving dialysis with catheter and in 69 patients undergoing dialysis with AVF (51.5%; $P < .001$).

The clinical characteristics of the patients are summarized in Table 1. The patients in the Palindrome group were older than those in the AVF group ($P < .001$) and had significantly lower serum albumin level ($P = .03$). However, the clinical characteristics were comparable between the Permcath group and Palindrome group. The reasons for application of long-term dialysis catheter included: long time for fistula surgery or the fistula healing (6 weeks); requiring immediate hemodialysis; acute renal failure, plan for early kidney transplantation or starting peritoneal dialysis; requiring transient alteration of peritoneal dialysis into hemodialysis; failure in preparation of vascular access at multiple sites and multiple times; requiring repair replacement of synthetic vascular access; requiring removal of peritoneal dialysis tube; and limited expecting survival time due to life-threatening diseases.

Sites of Catheter and Blood Flow

In the Permcath group and Palindrome group, the blood flow of catheter at the superior vena cava or outlet of the right atrium was higher than that of catheter in the right atrium (Table 2). Moreover, the blood flow in the Palindrome group was higher than

Table 1. Clinical Characteristics of Hemodialysis Patients by Vascular Access Type

Parameter	Hemodialysis Patient Groups		
	Permcath	Palindrome	AVF
Number of patients	43	49	56
Age, y	65 ± 14	71 ± 16*	50 ± 17
Male sex, %	29 (67.4)	35 (71.4)	46 (69.7)
Hemoglobin, g/L	84 ± 21	86 ± 20	91 ± 28
Serum creatinine, μmmol/L	589 ± 239	554 ± 220	601 ± 252
Serum albumin, g/L	34.0 ± 4.2	35.0 ± 4.4*	37.0 ± 4.7

Table 2. Sites of Catheters and Maximum Blood Flow

Parameter	Permcath*	Palindrome†	*P*
Superior vena cava			
Number of patients	31	14	
Maximum blood flow, mL/min	292 ± 31	351 ± 40	< .001
Right atrium			
Number of patients	12	35	
Maximum blood flow, mL/min	323 ± 35	418 ± 44	< .001

*P = .007 for comparison between sites for Permcath
†P < .001 for comparison between sites for Palindrome

that in the Permcath group, regardless of the sites of catheters. Among 130 patients receiving dialysis with long-term dialysis catheter, catheterization was done in the left internal jugular vein (Permcath, n = 4; Palindrome, n = 1). Statistical analysis was not done due to small sample size, but unilateral catheter dysfunction was frequently found. Only 2 patients undergoing catheterization via femoral vein developed catheter dysfunction. The above 7 patients were not recruited into analysis due to incomplete clinical information.

Dialysis Flow, Adequacy, and Catheter Function

The maximum blood flow in the Palindrome group was higher than that in the Permcath group (P < .001) and the AVF group (P < .001; Table 3). The single URR in the Palindrome group was significantly higher than that in the Permcath group (P = .007), but comparable to that in the AVF group (P = .06). The KT/V in the Palindrome group was higher than that in the Permcath group (P = .02), but similar to that in the AVF group (P = .49). The incidence of catheter dysfunction in the Palindrome group was markedly lower than that in the Permcath group (P = .045), but comparable to that in the AVF group (P > .99). The annual patency rate in the Palindrome was dramatically higher than that in the Permcath group (P = .04), but similar to that in the AVF group (P = .35). Nine patients receiving dialysis with long-term catheters experienced re-catheterization in the right atrium, achieving the improvement of catheter function. In addition, 5 patients with catheter dysfunction in the Permcath group received dialysis with Palindrome catheter.

Complications

In the Permcath group, 6 patients developed catheter-related infection, of whom 4 presented with perivascular access infection (2 with skin infection after re-catheterization) and 2 with intra-catheter infection (Table 4). In the Palindrome group, 6 patients developed catheter-related infection, of whom 5 presented with perivascular access infection (2 with skin infection after re-catheterization) and 1 with intra-catheter infection. The infection was controlled after local or systemic administration of antibiotics, and none underwent catheter withdraw. In the AVF group, 1 patient developed infection once. The incidence of access-related infection in the AVF group was markedly lower than that in the Permcath (P = .04) and Palindrome group (P = .048). In addition, 30.6% of patients in the

Table 3. Dialysis Flow, Adequacy, and Catheter Function by Vascular Access Type*

Parameter	Hemodialysis Patient Groups		
	Permcath	Palindrome	AVF
Maximum blood flow, mL/min	306 ± 38	391 ± 35	355 ± 51
Single urea reduction rate, %	58.6 ± 8.5	65.2 ± 9.4	68.6 ± 8.9
KT/V	1.28 ± 0.20	1.39 ± 0.24	1.43 ± 0.33
Catheter dysfunction	11 (25.6)	4 (8.2)	4 (7.1)
Annual patency rate	14 of 23 (60.9)	24 of 27 (88.9)	44 of 46 (95.6)

*Values in parentheses are percentages.

Table 4. Infections and Thrombosis by Vascular Access Type*

Parameter	Hemodialysis Patient Groups		
	Permcath	Palindrome	AVF
Access related infection	6 (14.0)	6 (12.2)	1 (1.8)
Thrombosis	21 (48.8)	12 (30.6)	3 (5.4)
Thrombosis related re-catheterization or a second fistula surgery	3 (7.0)	1 (2.0)	2 (3.6)

*Values in parentheses are percentages.

Palindrome group developed thrombosis, which was significantly lower than 46.5% in the Permcath group (P = .02) but significantly higher 5.4% in the AVF group (P = .01). There was no marked difference in the proportion of thrombosis related re-catheterization or a second fistula surgery.

DISCUSSION

The central venous long-term dialysis catheters are developed on the basis of transient catheters. The long-term dialysis catheters not only preserve the advantages of transient catheters but possess the characteristics for long-term indwelling catheter. In addition, these catheters have little influence on the hemodynamic and are feasible in the elderly, diabetic patients, patients unsuitable for preparation of AVF or peritoneal dialysis, patients with evidence of heart dysfunction, and those in the stage before the wound healing after AVF surgery. Moreover, the long-term dialysis catheters avoid repeated puncture, which make it acceptable by patients.[12,13]

Reports by the United States Renal Data System show 14.1% to 17.5% of dialysis patients receive dialysis with long-term catheters.[14] In the present study, only 17.4% of patients received dialysis with long-term catheters at the first dialysis, and about 50% of patients underwent dialysis with long-term catheters at the end of study. The reasons might be as follows; first, aging population increases in China, and increasing elderly patients receive dialysis. These patients have high incidence of secondary renal injury, and AVF surgery is difficult to perform in these patients.[9] In addition, the AVF dysfunction usually occurs in them. In the present study, patients receiving dialysis with long-term catheters had advanced age, poor general condition and low contents of hemoglobin and albumin when compared with those in the AVF group. Second, the major cause of uremia in China changes from glomerulonephritis to secondary renal injuries (such as diabetic nephropathy and hypertension). The vascular condition in these patients is very poor. In the present study, the major cause of renal failure in patients receiving dialysis with long-term catheter was secondary renal injury which accounted for 73.1% of causes of renal failure significantly higher than that in the AVF group (51.5%). Third, some dialysis patients are diagnosed with advanced uremia at dialysis due to poor medical resource and traditional perceptions. Thus, AVF surgery is infeasible in these patients, or patients should wait for a long time until their vascular condition is feasible for preparation of vascular access.[15] Fourth, in some centers for dialysis, physicians have inadequate skills on preparation of AVF.

Recently, the Dialysis Outcomes and Practice Patterns Study has shown that the survival of patients who alter dialysis with central venous catheter into dialysis via AVF or synthetic vascular access may improve to different extents, and the their mortality is reduced by about 30% when compared with patients continuing to receive dialysis with central venous catheter.[11] Lacson and coworkers conducted a cohort study on 79 545 patients receiving maintenance hemodialysis for more than 4 months, and similar conclusion was drawn.[16] Catheter withdraw not only improves the survival rate, but also elevates the quality of life in patients receiving hemodialysis.[13] The venous catheter as a foreign body is closely related to the high level of C-reactive protein in non-apparent infection condition. For new dialysis patients waiting for preparation of AVF, the C-reactive protein level is reduced by 82% when compared with those receiving dialysis with venous catheters,[17] and other parameters such as plasma albumin, normalized protein catabolic rate, estimated KT/V, hemoglobin, and leukocyte count are also improved.[18]

Long-term indwelling catheter has some complications, which mainly include catheter-related infection, thrombosis, formation of fibrous sheath, and stenosis of the central veins. In our center, a high incidence rate of catheter dysfunction, low blood flow, and high rate of recycling were also noted in patients receiving dialysis with long-term dialysis catheter. There is evidence showing that most of patients receiving dialysis with long-term dialysis catheter have advanced age, develop diabetes, and have a high risk for infection, thrombosis, and mortality, and the life span of vascular access is also shorter than that in patients receiving dialysis via the AVF.[10]

The Palindrome catheter has special "spiral-Z" tip and symmetrical double-D end, which avoids the reverse connection and significantly reduces the recycling rate. The special laser cutting furrow and smooth edge reduce the possibility

of coagulation and decrease the rate of catheter dysfunction. Findings in the present study showed the Palindrome catheter was superior to the Permcath catheter in the maximum blood flow, KT/V, and single URR in patients receiving dialysis. The incidence of catheter dysfunction in the Palindrome group was lower than that in the Permcath group, but the annual patency rate in the Palindrome group was higher than that in the Permcath group. On the basis of our findings and previously reported results,[15] we speculate that the sites of catheterization are crucial for the dialysis. It is better to catheterize via the right internal jugular vein and place the end of catheter in the right atrium. Once the catheterization is done via the left internal jugular vein or femoral vein, the catheter with appropriate length is necessary, and the short catheter might has compromised therapeutic efficacy and poor potency rate. In principle, catheterization is not done via the femoral vein.

The maximum blood flow, KT/V, and single URR were comparable between the Palindrome group and AVF group. Patients in the Palindrome group could also receive adequate dialysis. However, we did not recommend Palindrome catheter as the first choice for dialysis because patients receiving dialysis via the AVF have high blood flow, and low infection rate and low incidence of thrombosis. Thus, AVF is preferred vascular access for patients receiving long-term dialysis.[19] In the present study, the incidence of catheter-related infections was comparable between Palindrome group and Permcath group, but significantly higher than that in the AVF group. Although the incidence of thrombosis in the Palindrome was significantly lower than that in the Permcath group, but markedly higher than that in the AVF group. These support that catheter is not recommended as a preferred vascular access for patients receiving long-term dialysis.

Catheter-related blood-stream infection has a high incidence in clinical practice, which increases the risk for sepsis.[20-22] The strict aseptic procedures, timely intracatheter administration of urokinase, systemic thrombolysis, and administration of antibiotics and intracatheter hepatin may prolong the time of catheter indwelling and reduce the incidence of complications.[23-27] In our clinical practice, active and effective management of catheter-related complications is done and thus the incidence of re-catheterization due to thrombosis related complications was comparable between Palindrome group and Permcath group. Thus, successful catheterization, strict aseptic procedures and timely and effective management of complications may assure safe long-term dialysis with catheters.

CONCLUSIONS

Taken together, the Palindrome catheter is superior to previously used Permcath catheter in the blood flow, dialysis adequacy, and reducing incidence of catheter dysfunction. However, patients in the present study were evaluated in for a short period of time and the long-term influence of different catheters on the survival of dialysis patients is required to be further investigated in our future studies.

CONFLICT OF INTEREST

None declared.

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